Changes in universities' efficiency over the time: Differentials according to the missions

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Abstract

This paper examines the productivity of Spanish public universities from 2002 to 2004. The used of the Malmquist Productivity Index illustrates the contribution of efficiency and technological changes to productivity change over the period. Separate analyses of "teaching model", "research model" and "knowledge transfer-model" productivity are made. Moreover, some analysis about teaching quality, research quality and knowledge transfer quality are made to show how Spanish Higher Education System is developing their missions. Results suggest that on average the annual productivity growth was largely attributed to technological progress rather than efficiency improvements. Most of the productivity gain is attributed to improvements in research and knowledge transfer productivity rather than teaching.

Keywords
Productivity, Quality, Efficiency, Higher Education, University, Malmquist Productivity Index.

INTRODUCTION

Higher Education Institutions are undergoing important changes in the world. In the 1970s, the increased numbers of young people reaching higher education age accompanied by the rapid economic development that was occurring stimulated growth in higher education. As a consequence, universities became much bigger institutions, and new universities were established. In the second half of the 1970s and the beginning of the 1980s, higher education systems saw significant upward changes in their costs due, among other factors, to increased student numbers. This tendency stabilized towards the end of the 1980s, and by the end of the next decade student numbers had begun a slow decrease in some European countries. This motivated governments to implement strategies to measure universities' performance.

So, experts in higher education field affirm that the 21st century will be the most growth period of higher education in the history of education to world-wide level, the qualitative changes in the higher education system and like the period in which the use of public resources are forcing to make important readjustments in higher education institutions.

Although most of these changes followed the trend observable around the world, some were rather more specific to the Spanish context. Paramount among these changes was a rapid expansion of the system and its diversification, with the emergence of a strong private sector. Despite the growth of the private sector, public universities remained the backbone of the system. In fact, most private institutions are mainly teaching institutions with hardly any research activity. On the other hand, although the system of knowledge production has undergone important changes where we observe a diversification of the sites of knowledge production, universities remain at the centre of the system, while the growth of the other sectors (hospitals, industries…) is strongly linked to universities. Moreover, in the last two decades, the Spanish higher education system has undergone some political reforms. The Universities Act was reformed in 1983, 2001 and again in 2007.

The combination of these factors (among others) has created a special framework where different actors have to re-organise the system and one of their goals is to enhance the productivity and quality of higher education.

Universities receive public funds as a lump sum. In some regions, public funds to universities are allocated using formulas. These formulas are basically based on number of students, but also in some outcomes. Hence, in the last decades during which the number of students increased dramatically (until 1998) higher education financing and research funds have been greatly increased (driven by demand). After a period of rapid expansion, the Spanish university system faced a new and more difficult challenge in terms of improving the efficiency, productivity and quality of the system. However, the current decline in student numbers is extremely important. For the first time in the recent history of Spanish higher education, there is no guarantee that there will be a demand for the university places available. This could be a key factor for universities to adapt to a new era and to develop entrepreneurial activities in which the efficient use of available resources will become a key objective.

In addition, since the late 1980's, research activity has become an important part of the Higher Education System' source of incomes due to important legal framework changes in the way teaching staff can access research funds from the different administration levels (regional, national or European). In this respect the Spanish Higher Education System shifted from a model of pure education activity to a combination of both education and research activities.

Moreover, the promoting of the so-called third-mission activities at the universities might be seen as one of the major strategies adopted in recent years. A large debate is undergoing about the consequences of including among the institutional missions of universities, in addition to research and teaching, the so-called third mission. The third mission of universities is focused on commercialization of academic knowledge in the form of industry collaboration, patenting/licensing and the creation of spin-off companies. University-industry relations in the form of contract research and industrial sponsorship of academic science have a long history, while the engagement of universities and academics in patenting, licensing and the formation of new firms is a newer trend. Third mission activities are thus a complex mix, and subsequently also the development of coherent data sets and indicators are potentially complicated and pose some difficulties.

These issues have raised lots of discussions because the effect of these changes on the ability and effectiveness of universities are ambiguous. For example, the issue of third mission might be framed as a problem of complementarities vs substitution in outputs. The activities carried out by universities should be seen as a vector of outputs produced jointly, using the same vector of inputs. From this perspective, both positive and negative effects are plausible. In general, studies that examine single scientific areas find positive correlation between classical indicators of scientific activity and involvement into third mission activities, while studies that examine aggregate effects at university level more often find mixed results. Therefore, this evolution of the system has placed increasing emphasis on the relevance of assessing universities' performance in terms of productivity and also in terms of quality.
In this context, to carry out the assessment of universities activities is complicated due to their complex nature (Bonaccorsi & Daraio, 2005; García-Valderrama, 1996; Denison, 1962). They develop three important functions: knowledge production (particularly through R&D activities), knowledge transmission (through the training and the publication of research results), and knowledge transfer (by providing solutions to the specific problems of social and economic agents). In this sense, there are a lot of studies to measure these functions and activities. Using input and output systems, experts show if a university is efficient or not in knowledge production, knowledge transmission or knowledge transfer. However, there aren't so many studies that consider the trade-offs among teaching, research and the called "third mission". For this reason, the purpose of our paper is to gain insight into the measurement of productivity in higher education institutions, analyzing the possible existence of trade-offs among the Spanish public universities activities (teaching, research activities and knowledge transfer) from 2002 to 2004. Moreover, in this education, research and knowledge transfer setting, authors are broadly understood to make a statement about the quality of the graduate study programmes, about the variables that have influence of graduate research activities at industries and about graduate professional role transferring knowledge to firms.

Productivity in higher education has an obvious multidimensional character as it relates to both knowledge production and knowledge dissemination through its various forms of teaching, research and knowledge transfer (Dundar & Lewis, 1998). In this sense, measuring productivity in higher education context is complicated.

Changes in productivity growth over a period can be calculated using the Malmquist productivity change index. This approach is a particularly attractive method due to it does not require knowledge of input or output prices, nor does it require any specific behavioural assumptions of the institutions under consideration, such as cost minimization or profit or revenue maximization (Coelli & Perelman, 1999; O'Donnell & Coelli, 2003; Uri, 2003, 2003; Rodriguez-Alvarez, Fernandez-Blanco & Lovell, 2004; Johnes, 2005; Worthington & Lee, 2005).

Worthington & Lee (2005) examine the change in productivity in the Australian universities sector between 1998 and 2003, while Flegg *et al.* examine the change in productivity in the British universities sector over the period 1980/81 to 1992/93 (Flegg, Allen, Field & Thurlow, 2004). In both examples, the authors have used the non-parametric technique in which the selection of inputs and outputs in order to define the production function for modelling university behaviour (teaching, research and knowledge transfer) is complicated. Indeed, there is no definitive study to guide the selection of inputs and outputs (Tomkins & Green, 1988; Beasley, 1990, 1995; Johnes & Johnes, 1993, 1995; Glass, McKillop & Hyndman, 1995; Athanassopoulos & Shale, 1997). Most indicators are typical of the ambiguity found in education performance measurements (e.g. high degree results may be due to high entry qualifications rather than effectiveness of teaching) unable to capture the interaction among the various inputs and outputs (Gómez Sancho, 2001; Joumady & Ris, 2005) and the limitations with the selected output specification.

Studying output is found some complications. In the case of *teaching*, for example, one would prefer measures of the learning (concepts and competencies) that results from teaching such as number of students enrolled (Hanke & Leopoldseder, 1998), full-time equivalent students enrolled, student credit hours (Sinuany-Stern, Mehrez & Barboy, 1994), number of degrees conferred (Arcelus & Coleman, 1995), PhD graduated, among others, but indeed some problems arisen. For instance, credit hours can differ significantly among programs of full-time students (e.g. science students with labs versus humanities students) and these differences more likely reflect input differences than learning differences. Degrees awarded measure completions and a level of accomplishment or extent of learning, but they neglect the education of those who attend but do not graduate and do not recognize differences in the length of degree programs (within or across universities), such as between three and four year undergraduate programs, which the full-time equivalent enrolment capture. Cohn & Santos (1989) remarked that graduated student represents an accumulated output for many years depending of degree time, although it is not computed the effort of non-graduated students and there are not quality criteria.

On the other hand, *research* output is also difficult to measure. Ideally, one would like an index that reflected the quality and impact of the activities undertaken and their products, but no such index exists. Publication counts are sometimes available and used as a measure of research output (Van de Panne, 1991; Arcelus & Coleman, 1995), although sometimes publication counts are difficult to obtain and are typically incomplete. For example, the publication count variable used by De Groot, McMahon & Volkwein (1991) in their study of the cost structure of US research universities omitted publications from the humanities. Other useful output would be books, book chapters and refereed journal articles and conference proceedings but this information is not always available. Sarafoglou & Haynes (1996) use number of articles and a citation impact factor. Tomkins & Green (1988) use both publications counts and grants. Lacking reliable and easily obtainable output measures, many studies substitute research grants, an input, as a proxy for research output (Rhodes & Southwick Jr, 1986; Ahn, Charnes & Cooper, 1988; Tomkins & Green, 1988; Cohn & Santos, 1989; Ahn & Seiford, 1993). Ahn, Arnold, Charnes & Cooper (1989) blend this approach using state funds allocated to state institutions of higher education as input and federal and private research funds as output.

In the case of inputs although there are many kinds of them — for example, faculty, support staff, student services, libraries, computers, equipment and supplies, maintenance, buildings, etc. — they can usually be defined relatively well in terms of amounts or expenditures. Traditionally, it is used the undergraduate student number or doctoral student number (Ahn & Seiford, 1993; Athanassopoulos & Shale, 1997; Hanke & Leopoldseder, 1998; García-Aracil, 2006) for both as a teaching and a research input; academic and non-academic staff measured as the full-time equivalent or as number (Van de Panne, 1991), or by staff cost (Ahn, Charnes & Cooper, 1988; Hanke & Leopoldseder, 1998). Moreover total expenditure is used like input (Ahn, Charnes & Cooper, 1988) and its breakdown in R&D expenditures (Ahn, 1987), capital expenses (Johnes, 2005), library expenses (Rhodes & Southwick Jr., 1986), computer services and structures (Ahn, Charnes & Cooper, 1988; Ahn & Seiford, 1993; Ahn, Arnold, Charnes & Cooper, 1989), and/or space (Bessent & Bessent, 1980). Variations in input quality, however, may not be easily distinguished.

It should be remarked that there are some variables with no consensus to consider them as input or as output like the case of number of undergraduate students, research income, research grants and so on. In addition, measures for assess the knowledge transfer are difficult to obtain.

Thus, in the absence of any specific measurement to evaluate HEI, in this paper we have applied the Malmquist non-parametric approach to analyze the productivity change of the Spanish public universities from 2002 to 2004 including the following variables: as inputs we consider the total expenditure, academic staff and non-academic staff (proxy to measure teaching, research and knowledge transfer), and as output, we include number of graduates (proxy to measure education), publication (proxy to measure research) and total amount of applied research (proxy to measure knowledge transfer).

As it has been shown above, university mission is a complex issue that will be best assessed and evaluated using multiple techniques and broadly-based criteria. For that reason, we complement productivity analysis with quality analysis. We understand that evaluation has to be used to give an overview of particular settings. Informed judgements on teaching, research or knowledge transfer effectiveness can best be made when both assessment and evaluation are conducted, using several techniques to elicit information from various perspectives on different characteristics of the evaluated object. Moreover, if multiple perspectives are represented and different techniques used, the process will be more valued and the conclusions reached will be more credible (SCOTL, 2002).

The remainder of the paper is organized as follows. In Section 2 presents the data descriptive; Section 3 briefly addresses the methodology. Section 4 explains the results of the productivity and quality analysis and Section 5 contains the concluding remarks.

DESCRIPTION OF THE DATA

Sources of data

The data set used at productivity analysis was collected under the project *Advanced Quantitative Methods for the Evaluation of the Productivity of Public Sector Research*
(AQUAMETH) within the framework of PRIME, a European Network of Excellence, which is supported by the Union Sixth Framework Programme (2002-2006).

Data was collected from various governmental and institutional sources from the academic year 1994/95 to 2004/2005 and pertain to public universities in Spain. In 2004, there were 48 public institutions. In this study we consider 47 of them. The remaining university -National Open University (UNED) - is excluded due to its different structure.

The AQUAMETH data set includes information for each public institution related to the accounting system based on a broad classification system of appropriations and expenditures; human resources data providing information about the academic and non-academic staff; enrolment data for undergraduate and graduate programs; institutional information on the physical resources and publications data; and applied research.

On the other hand, the data set used in quality analysis was taken from a major representative survey comparing the study programme and the situation of European higher education graduates. More than 39,000 graduated students were surveyed about five years after graduation (graduates from 1999/2000 were surveyed in 2005/2006). The study named REFLEX (Flexible Professional in the Knowledge Society New Demands on Higher Education in Europe), which it was funded by the EU 6th Framework Program, includes graduates from fifteen countries, although we have only taken into account Spanish graduates (for a full description of the survey see: Koucky, Meng and van der Velden, 2007).

Descriptive data

Next, it is presented some basic data descriptive. We select those variables related with the inputs and outputs selection according to the purpose of this study as we mentioned above: total expenses, academic and non-academic staff, graduates, publications and applied research.

The total expenses is based on a broad classification system and refers to the expenditure in academic staff, expenditure in non-academic staff, running expenses in goods and services, financial expenditures, flow of funds, capital expenses, real investment, and other expenses (financial assets plus financial liabilities). The amount is expressed in thousand euros (CRUE, 1996, 1998, 2000, 2002).

The academic and non academic staff refers to number of people that works in the university (independently of the labour they made). In Spain, the position of researchers does not exist as an independent category. The academic staff has both teaching and research duties, although there are no clear rules on research duties for academic staff. The non-academic staff is the technical and administrative staff (INE, several years).

Data concerning graduates refers to the number of people that degrees attributed between the first day of January and the last of December of each year, and corresponds to the academic year that ends up that year (CCU, 1999; 2003, 2004).

Publication refers to the number of publications that the university has published. Data is from the Web of Science consists of five databases, but it have only used three of them, Sciences Citation Index Expanded, Social Sciences Citation Index, and Arts and Humanities Citation Index. One of the problems has been found is that the year refers to the year that an article's information was entered into the database and not necessarily when the source article was published. Other additional problem is that the number of publication per public university was calculated through global counting. This implies that if in one article there are several universities being mentioned, the article is counted one time per each university. Moreover, if one article was attributed to more than one scientific field, it has been counted as many times as the number of scientific fields (Web of Science, 2005).

Applied research is research accessing and using some part of the research communities' (the academy's) accumulated theories, knowledge, methods, and techniques, for a specific, often state, commercial, or client driven purpose. Applied research is often opposed to pure research in debates about research ideals, programs, and projects (Trochim, 2006).

The next table (Table 1) presents a summary of the descriptive statistics for inputs and outputs across the 47 universities by year. Sample mean, standard deviation, maximum, minimum, skewness and kurtosis are reported. It can be seen that in 2004 on average expenses totalled 156 million euros with 1,852 academic staff and 921 non-academic staff, i.e. there was one technical/administrative staff member for every two academic staff. It can also be seen that, on average, Spanish universities granted 3,614 degrees, produced 498 publications and performed applied research to the value of 5 million euros. Over the sample period, we can see that on average expenditures increased by 24.81 per cent (from 125 million euros in 2002 to 156 million euros in 2004), academic staff increased by 5.24 per cent (from 1,760 to 1,852), non-academic staff increased by 6.10 per cent (from 868 to 921), number of graduates decreased by 13.87 per cent (from 4,196 to 3,614), number of publications increased by 13.77 per cent (from 437 in 2002 to 498 in 2004) and applied research increased by 38.73 per cent (from 3 million euros to 5 million euros). It could be said that, with the exception of the reduced number of graduates, these increases in inputs positively affected the increase in outputs.

Table 1. Descriptive statistics for inputs and outputs across the 43 universities by year.

Year 2002							Applied Research
	Statistics	Expenses	Academic	Non-acad.	Graduates		*(thousand*
	Mean	*(thousand €)*	Staff	Staff	*(number)*	Publications	*€)*
	Std.desviation	124,996.82	*(number)*	*(number)*	4,196.30	*(number)*	3,706.46
	Minimum	81,382.25	1,760.23	868.26	3,285.93	437.47	3,524.55
	Maximum	28,227.68	1,199.40	640.32 217	826	410.71 22	402.39
	Skewness	419,468.33	419 6,021	3,509 2.11	15,770	2,150 2.15	13,475.95
	Kurtosis	1.62 3.07	1.58 2.84	5.99	1.46 2.31	6.15	1.42 1.12
	Mean	140,501.82	1,810.28	908.28	4,178.40	495.86	4,424.22
	Std.desviation	91,651.96	1,193.03	646.04 235	3,172.51	442.25 41	4,035.72
	Minimum	31,895.49	305 5,961	3,540 2.03	630	2,250 1.97	379.21
2003	Maximum	454,347.56	1.50 2.50	5.55	13,826	4.82	15,362.36
	Skewness	1.63 2.88			1.30 1.08		1.35 0.90
	Kurtosis						
	Mean	156,006.82	1,852.28	921.19	3,614.35	497.72	5,141.98
	Std.desviation	104,681.82	1,192.84	663.56 236	2,644.52	440.35 71	4,966.53
	Minimum	32,650.32	477 5,896	3,563 1.96	267	2,238 1.99	94.31
	Maximum	489,370.91	1.48 2.21	4.94 6.10%	13,924	4.88	19,625.78
	Skewness	1.72 3.21	5.24%		1.76 4.32	13.77%	1.50 1.62
2004	Kurtosis	24.81%			-13.87%		38.73%
02-	Mean						
04	Variation						

The distributional properties of all six variables are shown in the table below. They appear non-normal. Given that the sampling distribution of skewness is normal with a mean of 0 and standard deviation of $\sqrt{T/6}$ where T is the sample size, many of the series are significantly skewed. Since these are also positive they signify the greater likelihood of observations lying above rather than below the mean. Across each year in the sample period, the most highly skewed variables are non-academic staff and graduates. The kurtosis or degree of excess across some variables is also large, indicating leptokurtic distributions with extreme observations. Given that the sampling distribution of kurtosis is normal with a mean 0 and standard deviation of $\sqrt{T/24}$ where T is the sample size, many of the estimates are statistically significant at any conventional level. Non-academic staff and graduates are again highly leptokurtic.

Moreover, Table 2 presents some data about the surveyed graduated students under the REFLEX project. We present only data related with Spanish graduates. As we can see more than 60 percent of surveyed graduates were female. Almost all graduates were between 26 and 35 years old (95.35 percent). The most representative discipline was Social Sciences
(34.76 percent) and the lowest was Mathematics (13.89 percent). The others ones were more or less equal.

Table 2. Description of the sample surveyed under the REFLEX project

Variables	Percentage	
Gender	Female 62.18 Male 37.82	
Age	<26 0.0 26-30 70.76 31-35 24.59 36-40 2.91 >40 1.74	
Field of study	Humanities Social Sciences Mathematics Engineering Health	20.84 34.76 13.89 14.45 16.06
Full-time students	Yes	82.92
More studies	Yes	57.07

We can also see that Spanish students are full-time students and finally that more than half of the sample acquired higher level of studies after their graduation.

With the analysis of quality we have explain how this characteristics, among other, have influence at graduates opinions about their study programmes, about the graduate research activities at industries and about graduate professional role transferring knowledge to firms.

METHODOLOGY

Once of the methodologies employed in this paper to study productivity growth in the Spanish public Universities from 2002 to 2004 is the nonparametric Malmquist index. This productivity growth method is superior to alternative indexes such as the Törnqvist index or the Fisher Ideal index, because Malmquist index is based only on quantity data and makes no assumptions regarding university's behavior.

Several different decompositions of the Malmquist index have been proposed in the literature. One of them is that proposed by Fare, Grosskopf, Norris & Zhang (1994) which assumes constant returns to scale (CRS) technology. Other is that proposed by Ray & Desli (1997), which does not require the CRS assumption. Simar & Wilson (1998) and Zofío & Lovell (1998) extend the Ray & Desli (1997) decomposition, more concretely, the technical change component further decomposed into a "pure" technical change of the frontier plus a residual measure of the scale change of the technology. This residual measure evaluates the separation between the CRS and the variable returns to scale (VRS) technologies.

In this study, we assume constant returns-to-scale to start with, and calculate the total productivity change and decomposed into technological (or technical) change and technical efficiency change which is formed by "pure" efficiency change and scale efficiency change.

Furthermore, for studying productivity by Malmquist, it is necessary to construct a nonparametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. There are two analysis options: input orientation which reduces the inputs without dropping the output levels, and output orientation which raises outputs without increasing the inputs. In education, the universities may be given a fixed quantity of resources (e.g., state financial resources, academic and non-academic loads) and asked to produce as much output as possible. Thus, we assume an output orientation.

The output-based Malmquist productivity change index *(M)* specified by Fare, Grosskopf, Norris and Zhang (1994) may be formulated as:

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where the subscript *O* indicates an output-orientation, *M* is the productivity of the most recent production point (x^{t+1}, y^{t+1}) (using period $t + 1$ technology) relative to the earlier production point

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(x^t, y^t) (using period *t* technology), D^0 are output distance function which is the reciprocals of Farrell's (1957) technical efficiency measures. The output distance function, it is defined on the output set $P(x)$, as: $D_o(x,y)$:min {θ : (y/θ) □ P(x)} where θ �is the corresponding level of efficiency. The output distance function seeks the largest proportional increase in the observed output vector *y* provided that the expanded vector (*y*/θ) is still an element of the original output set (Grosskopf *et al.*, 1995). If the university is fully efficient, so that it is on the frontier, $D_o(x,y)= \theta =1$, where as $D_o(x,y)= \theta <1$ indicates that the institution is inefficient. An equivalent way of writing the Malmquist index is:

$$M_o(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{D_o^{t+1}(y_{t+1}, x_{t+1})}{D_o^{t}(y_t, x_t)} * \left[\frac{D_o^{t}(y_{t+1}, x_{t+1})}{D_o^{t+1}(y_{t+1}, x_{t+1})} \cdot \frac{D_o^{t}(y_t, x_t)}{D_o^{t+1}(y_t, x_t)} \right]^{1/2}$$

or *M=E*P* where *M* is the product of a relative efficiency change *E* under constant returns to scale which measures the degree of catching up to the best-practice frontier for each observation between time period *t* and time period *t + 1* (term outside the square bracket) and a measure of technical progress *P* (the two ratios in the square bracket) as measured by shifts in the frontier of technology (or innovation) measured at period *t + 1* and period *t* (averaged geometrically). Applying at the same data CRS assumption (without convexity constraint) and VRS (with convexity constraint), measures of overall technical efficiency *(E)* and "pure" technical efficiency *(PT)* are obtained. Dividing the overall technical efficiency *(E)* by "pure" technical efficiency change *(PT)* then yields a measure of scale efficiency change *(S)*.

Recalling that *M* indicates the degree of productivity change, then if $M>1$ then productivity gains occur, whilst if $M<1$ productivity losses occur. Regarding changes in efficiency, technical efficiency increases (decreases) if and only if *E* is greater (less) than one. An interpretation of the technological change index is that technical progress (regress) has occurred if *P* is greater (less) than one.

To calculate the indices, it is necessary to solve several linear programs to maximize the function with the premises. Assume there are *N* universities and that each university consumes varying amounts of *K* different inputs to produce *M* outputs. The *ith* university is therefore represented by the vectors $x_i y_i$ and the $(K \times N)$ input matrix *X* and the $(M \times N)$ output matrix Y represent the data of all universities in the sample. The first two linear programs are where the technology and the observation to be evaluated are from the same period, and the solution value is less than or equal to unity. The second two linear programs occur where the reference technology is constructed from data in one period, whereas the observation to be evaluated is from another period. The following linear programs are used:

$$[D_0^{t+1}(y_{t+1}, x_{t+1})]^{-1} = \max_{\theta,\lambda} \theta \qquad [D_0^{t}(y_{t}, x_{t})]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $-\theta y_{i,t+1} + Y_{t+1}\lambda \geq 0$, s.t. $-\theta y_{it} + Y_t\lambda \geq 0$,

$x_{i,t+1} - X_t\lambda \geq 0$ $x_{it} - X_t\lambda \geq 0$

$\lambda \geq 0$ $\lambda \geq 0$

$$[D_0^{t}(x_{t+1}, y_{t+1})]^{-1} = \max_{\theta,\lambda} \theta \qquad [D_0^{t+1}(y_{t}, x_{t})]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $-\theta y_{i,t} + Y_{t+1}\lambda \geq 0$, s.t. $-\theta y_{i,t+1} + Y_t\lambda \geq 0$,

$$y_{t,i} - X_t\lambda \geq 0 \quad x_{t+1,i} - X_t\lambda \geq 0$$

$$\lambda \geq 0 \quad \lambda \geq 0$$

This approach can be extended by decomposing the constant returns-to-scale technical efficiency change into scale efficiency and pure technical efficiency components. Further details on the interpretation of these indices may be found in Charnes, Cooper, Lewin & Seiford (1993), Lovell (2003), Worthigton & Lee (2005).

On the other hand, to analysis the teaching, research and knowledge transfer quality we have applied the ordered probit regression. This kind of analysis is appropriate to reflect the ordinal character of the answers.

This model is what Agresti (2002) calls a *cumulative link* model. The basic interpretation is as a *coarsened* version of a latent variable *Y_i* which has a logistic or normal or extreme-value or Cauchy distribution with scale parameter one and a linear model for the mean. The ordered factor which is observed is which bin *Y_i* falls into with breakpoints

$$zeta\_O = -Inf < zeta\_1 < \dots < zeta\_K = Inf$$

This leads to the model

$$logit\,P(Y <= k \mid x) = zeta\_k - eta$$

with *logit* replaced by *probit* for a normal latent variable, and *eta* being the linear predictor, a linear function of the explanatory variables (with no intercept).

RESULTS

Table 3 shows us the results of our productivity analysis. We can see three columns, one for each model that presents the results by years. The letter M presents the total productivity change over the period. This is decomposed in both: Technical efficiency change represented by letter E and Technological change by letter P.

Table 3. Malmquist index by year, 2002-2004.

Year /	Teaching Model			Research Model			Knowledge Transfer Model
index	E	T PT S	M	E	T PT S	M	E T PT S M
2002	-21.3	33.6 -14.4 -8.0	5.1	3.3	1.9 4.6 -1.3	5.2	-11.8 6.9 -8.4 -3.8 -5.7
2003	-11.8	6.5 -6.0 -6.2	-6.0	13.9	-4.0 8.9 4.7	9.3	-15.3 33.3 -9.3 -6.7 12.9
2004	37.3	-38.1 21.7 12.8	-15.0	6.8	-9.6 8.0 -1.1	-3.4	-16.3 23.5 -7.7 -9.4 3.3
All years	-1.6	-4.1 -0.7 -0.9	-5.6	7.9	-4.0 7.2 0.7	3.6	-14.5 20.8 -8.5 -6.6 3.2

The “teaching model” showed an annual mean decrease in total factor productivity of -5.6 percent for the period across the university sector. That is composed of an average efficiency decrease of 1.6 percent and average technological decrease of -4.1percent.

The “research model” showed an annual mean increase in total factor productivity of 3.6 percent for the period across the university sector. That is composed of an average efficiency increase of 7.9 percent and average technological decrease of 4.0 percent. So them, annual productivity was attributed to efficiency improvement rather than technological progress.

At “knowledge transfer model” we can also see an annual mean increase in the total factor productivity. But, in this case was attributed to technological progress (20.8 percent) rather than efficiency improvement (-14.5 percent).

The highest mean productivity improvement was in academic year two thousand and three at the knowledge transfer model with an average productivity of 12.9 percent.

On the other hand, Table 4 presents the results of probit regression analysis in teaching model. So, if we see the odered probit regression in teaching model, gender is only significant when we ask graduates what extent has been their programme for future career. We can see that females think that their programme is not a good basis for their future career.

Disciplines are not significant for performing current works tasks. But, engineering is better discipline than social sciences for further learning on the job, meanwhile humanities is worse. It could be remarked that mathematics and engineering are worse disciplines than social sciences for student personal development; it could be because graduates in social sciences have to do some kind of activities which allow the development of personal characteristics.

If we focus on qualifications, we can see that high qualifications are better for starting work and for further learning on the job. That is, high qualification is a good skill when graduates finish their studies, but it doesn't when graduates are at the labor market for years.

Unlike we expected, it is more significant an academically prestigious programme on the graduates opinions about their programmes than, for example, vocational oriented programme which is an important factor at European level.

About the mode of teaching we can see that there are some which are significant. But, practical knowledge is the most strength mode.

Table 4. Ordered probit regression in teaching model

	Star to work	Further learning job	Perform current tasks	Future career
	Coef. P>z	Coef. P>z	Coef. P>z	Coef. P>z
Female	-.0588526 0.142	.004171 0.917	-.029062 0.464	**-.1078935** 0.006
Humanities	**-.123988** 0.031	-.303304 0.000	-.078883 0.172	**-.1821319** 0.001
Mathematics	.0148906 0.809	-.0539304 0.379	-.0048868 0.937	-.242313 0.000
Engineering	**.3826028** 0.000	.2305418 0.000	.0601015 0.353	-.0001671 0.998
Health	**.1763111** 0.003	.0395344 0.495	.093109 0.109	**-.1298211** 0.024
Average score: low	**-.1537539** 0.000	-.1332118 0.000	**-.1227588** 0.001	-.0731574 0.051
Average score: high	**.1754631** 0.034	.0761089 0.350	**.2192737** 0.007	.0398532 0.620
Regarded as demanded	.0743655 0.003	.0821313 0.001	.0353586 0.157	.0425384 0.085
Employers are familiar	.0498127 0.010	.0472089 0.013	.0709792 0.000	.0903218 0.000
Freedom in composing it	.0068052 0.681	.0168706 0.303	-.0036366 0.825	-.0088094 0.588
Broad focus	-.0239131 0.328	.0161843 0.504	-.0154202 0.524	-.0007412 0.975
Vocationally oriented	-.0195668 0.431	.0270483 0.272	.0247761 0.314	.0258551 0.290
Academically prestigious	**.2487647** 0.000	**.1733364** 0.000	**.1532065** 0.000	**.2062061** 0.000
Lectures	.047275 0.004	.0438924 0.007	.0419713 0.011	.0236613 0.147
Group assignments	-.0124016 0.570	.0242678 0.262	-.0558564 0.010	-.0075162 0.727
Participation in projects	-.0731155 0.001	-.0089294 0.668	-.0226192 0.278	.0001583 0.994
Internships, work placement	.058327 0.002	.0292049 0.123	.0544392 0.004	.0357522 0.057
Practical knowledge	.0869307 0.000	**.136844** 0.000	**.1370811** 0.000	.0749338 0.000
Theories and paradigms	-.0360847 0.082	.0198449 0.335	-.0381709 0.064	.0154855 0.450
Teacher	.0237866 0.258	.0019785 0.924	-.0042632 0.838	.0146538 0.479
Problem-based information	.0641948 0.002	.0794484 0.000	.0553938 0.006	.0497882 0.014
Written assignments	-.0457081 0.041	-.0162552 0.462	-.029484 0.184	-.007906 0.720
Oral presentation by student	.0271269 0.199	.0096134 0.646	.069243 0.001	.041338 0.047
Multiple choise exams	.0085815 0.594	-.0160061 0.317	.0066309 0.678	.0141721 0.373
Part-time student	**-.164439** 0.002	-.0902016 0.083	-.0541887 0.296	.0945507 0.069
Work placement/internship	**.1453296** 0.001	.0402969 0.364	-.0313182 0.481	-.0056995 0.897
Study-related work exp	**.2143757** 0.000	**.2542612** 0.000	**.2393279** 0.000	**.1265408** 0.004
Non Study-related work exp	-.0608173 0.115	-.0286139 0.455	-.1056396 0.006	-.027079 0.477
Observations	3653	3643	3576	3643

LR chi2(28)	837.28	706.30	530.69	499.03
Log likelihood	-5263.9226	-4996.2003	-5321.4651	-5231.0671
Pseudo R2	0.0737	0.0660	0.0475	0.0455

Moreover, we have applied another probit regression to study research performance. To do that, we have asked if "external factors -enterprises, firm context and so on- have more impact than internal factors -competencies, study level, so on- in graduated students to play a role in introducing innovation in their organization". Analyzing this relationship we will be able to understand if universities had a key role on promoting students to develop research activities in their organizations. Table 5 shows the results.

Table 5. Ordered probit regression in research model

		Research Model
		Coef. P>z
Internal factors	Group assignments	-.0399946 0.098
	Participation in projects	.0510014 0.049
	Internships, work placement	-.0170802 0.391
	Practical knowledge	.0224036 0.376
	Problem-based information	.0331793 0.166
	Oral presentation by student	.0527599 0.028
	Higher level of education	.0987185 0.028
	Occupation: professionals	**.7231142** 0.000
	Acquire new knowledge	-.0345995 0.107
	Negotiate effectively	.0218791 0.180
	New opportunities	.0631756 0.001
	Use time efficiently	**-.1077325** 0.000
	Work productively with others	-.001497 0.934
	Come up with new ideas	**.1712191** 0.000
	Question your own ideas	-.0108692 0.612
	Present products or ideas	.0317467 0.063
Externalfactors	Sector: private	**.5980031** 0.000
	Extent of innovat: products	.0249726 0.392
	Extent of innovat: technology	.0620696 0.036
	Extent of innovat: knowledge	**.2593689** 0.000
	Adopting innovations	-.0170654 0.498
Observations		3916
LR chi2(28)		1095.88
Log likelihood		-2164.268
Pseudo R2		0.2020

Although there are some modes of teaching (participation in projects, oral presentation by student) that are significant, we can see that their strength is not too high. Moreover, higher level of education is significant, but it also has a low strength. However, the current activity at work it is a significant variable with a strong impact. So, those graduates who are working at professional jobs or technicians and associate professional jobs have higher probability to play a role in introducing innovations (productservice, technology-tools-instruments or knowledge-methods innovations) in their organizations than, for instance, managers-senior officials or those who develop elementary jobs.

On the other hand, there are some significant competencies with a high strength such as ability to come up with new ideas and ability to use time efficiently. It is important to remark that they are opposites; meanwhile “come up with new ideas” has a positive effect, “use time efficiently” has a negative impact.

As we expect, to work in a private sector is significant with a high strength. It is an obvious result because private enterprises have to compete in the market stronger than public organizations.
Finally, it is significant to graduates play a role in introducing innovations in their organizations the fact that organizations develop extended innovations with respect to technology, tools or instruments innovations and knowledge or methods innovations. However, if organizations develop products or services innovations is not significant. We think that it is because, at least at Spanish context, these innovations are firm strategies to win competitiveness saving productions cost or rising commercials success and, probably, this kind of innovation depends on managers or executive directors.

To conclude, we have applied a third probit regression to study knowledge transfer activities. In table 6, we can see that there are some significant variables that could explain if graduates are being considered as an authoritative source of advice by their professional colleagues at job, if they keep their professional colleagues informed about new developments in their field work and if graduates establish professional contacts with experts outside the organization.

Table 6. Ordered probit regression in Knowledge Transfer model

	Authoritative source of advice	**Keep professional colleagues informed**	**Take the initiative to establish professionals contacts**
	Coef. P>z	**Coef. P>z**	**Coef. P>z**
Occupation: legislators Occupation: professionals Occupation: clerk Occupation: services Occupation: elementary	-.0226612 0.819 - **.1492432** 0.015 - .0314424 0.668 .019014 0.866 - .1956571 0.142	**-.3314372** 0.001 **-** **.1311445** 0.032 **-** **.2078825** 0.005 **-** **.2338395** 0.039 **-** **.5621809** 0.000	.1537413 0.117 .0705264 0.254 - **.3849075** 0.000 - .0600211 0.603 - .6338172 0.000
Type of contract: unlimited term	**.1759127** 0.000	.0332247 0.372	-.0491407 0.195

Sector: private	**.2183415** 0.000	-.0935074 0.021	-.041801 0.311
Scope: regional	-.0905652 0.097	-.010275 0.850	-.0335711 0.543
Scope: national	-.1050971 0.055	.0220634 0.686	.0588778 0.288
Scope: international	-.0984832 0.087	.0509793 0.373	.0997571 0.086
Responsible: set goals for the org.	**.1183059** 0.000	**.1131399** 0.000	.2042403 0.000
Responsible: decide how do your job	**.1953255** 0.000	**.1729111** 0.000	.130756 0.000
Mastery of your own field	.0617557 0.000	.0673679 0.000	.0317913 0.043
Analytical thinking	.0445292 0.004	.063665 0.000	.0850306 0.000
Mobilize the capacities of others	.0568999 0.000	.0657358 0.000	-.0042144 0.759
Negotiate effectively	.0703333 0.000	.0290331 0.016	.0909967 0.000
Come up with new ideas	.049485 0.003	.0808373 0.000	.0597412 0.001
Observations	3916	3916	3916
LR chi2(28)	811.64	792.95	1028.53
Log likelihood	-6005.9849	-6300.0077	-6227.7306
Pseudo R2	0.0633	0.0592	0.0763

There are external factors (those related with organization) and internal factors (those related with graduates) which are significant in predict the dependent variable.

Looking at occupations, we can conclude that those graduates who develop a professional occupation are little considered as an authoritative source of advice by their professional colleagues than those who develop others activities. With respect to the fact that graduates keep their professional colleagues informed about new developments in their field work, we can say that occupations are significant; especially strong are elementary occupations and legislators employees. Taking into account the professional contacts established with experts outside the organization, we see that clerks and elementary jobs establish fewer contacts than other occupations.
Moreover, graduates with unlimited term contract are more considered as an authoritative source of advice than those with fixed-term contract. This result shows us that unlimited term contracts are better to reach an expert employee than others type of contracts. There are quite literature which explains this result. But type of contract is not significant to graduates keep their professional colleagues informed about new developments and to take the initiative in establishing professional contacts with experts outside the organization. Additionally, we can say that meanwhile working in a private firm is significant to be considered as an authoritative source of advice and to keep their professional colleagues informed about new developments, it does not for taking the initiative in establishing professional contacts with experts outside the organization.

We can also see that those graduates who have responsibilities on setting goals for the organization and deciding how they do their own job are more considered such as an authoritative source of advice, they keep their professional colleagues more informed about new developments in their field work and they take the initiative in establishing professional contacts higher extent than those who do not.

Finally, we can say that graduates with analyzed competencies (analytical thinking, ability to come up with new ideas and solutions and so on) will transfers knowledge to firms in the studied terms.

CONCLUSIONS

We can conclude that there are differences between models:

- The annual productivity growth (drop) in teaching model was attributable to increase (decrease) in technical efficiency.
- The annual productivity growth in research model was largely attributable to efficiency improvements rather than technological progress.
- The annual productivity growth in knowledge transfer model was largely attributable to technological progress rather than efficiency improvements.

With exceptions, gains in scale efficiency appear to have played a minor role in productivity gains. And finally, we can say that most productivity growth was associated with improvements in research and knowledge transfer than teaching.

If we focus on quality analysis, we can see that there are some characteristics that let us predict if a programme will be a good basis for starting work, for further learning on the job, and so on (teaching model). Moreover, we have analyzed if external factors have more impact than internal factors in graduated students to play a role in introducing innovation in their organization (research model). Finally, we have tried to assess if universities are training students to transfer their knowledge and skills outside universities (knowledge transfer model).

We have seen that both, external and internal factors are significant to explain if universities had a key role on promoting students to develop research activities in their organization. However, internal factors are more significant to explain how students transfer knowledge to firms than external factors.

Although our results are preliminary results, they permit us to understand how universities are developing their missions. To complete this study, we want to do additional specifications and more detailed interpretations in further analyses.

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